Army High Performance Computing Research Center

AHPCRC Bulletin

Volume 1 Issue 3

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Lightweight Combat Systems Survivability

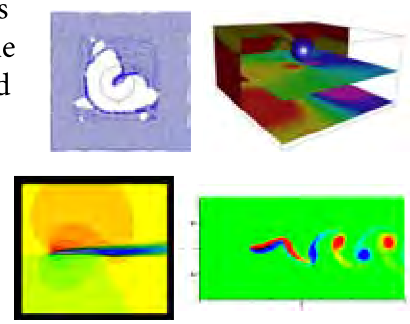
INSIDE THIS ISSUE

The Army High Performance Computing Research Center, a collaboration between the U.S. Army and a consortium of university and industry partners, develops and applies high performance computing capabilities to address the Army's most difficult scientific and engineering challenges.

AHPCRC also fosters the education of the next generation of scientists and engineers—including those from racially and economically disadvantaged backgrounds—in the fundamental theories and best practices of simulation-based engineering sciences and high performance computing.

AHPCRC consortium members are: Stanford University, High Performance Technologies Inc., Morgan State University, New Mexico State University at Las Cruces, the University of Texas at El Paso, and the NASA Ames Research Center.

Strong, impact-resistant materials lighten the soldier's load, give the soldier increased protection, and minimize risk of injury. Computer simulation allows designers to compare and evaluate numerous mechanical and material configurations without the time and expense of building physical models. Complex, realistic computer simulations enable more sophisticated and intentional approaches to material design and better understanding of a material's modes of deformation and failure.



Computer simulations, clockwise from top left: Ballistic impact on protective fabric; ballistic impact on a soft target; air flow in the wake of a flapping wing; airfoil pressure contour map. (All graphics courtesy of the researchers.)

Soldier survivability is also increased by using mechanical devices, such as automated aerial drones, to stand in for humans where hazardous or tedious work is involved. Computer simulations assist in developing mechanical designs that exploit solutions already in use by biological organisms. Streamlined, massively parallel high performance computing structural codes allow researchers to examine many relevant physical factors simultaneously, or to examine parameters in isolation (often not possible in the physical world), thus creating models that more closely simulate—or improve on— real-world phenomena.

In this issue of the AHPCRC Bulletin, we introduce the projects in AHPCRC's Lightweight Combat Systems Survivability technical area and the researchers working on these projects. Also inside: awards and recognition received by AHPCRC consortium partners, and a list of publications and presentations based on AHPCRC research. ✭

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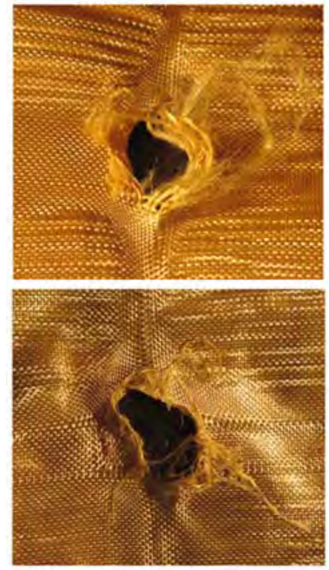
Multiscale Ballistic Fabric Nets

Body armor ranks with water, ammunition, and weapons as one of the heaviest items worn or carried by troops, according to engineers on the Ballistics Technology Team at the U.S. Army Soldier Systems Center (Natick, MA). Protecting soldiers and their vehicles and equipment from flying projectiles requires shielding that resists penetration and that is lightweight enough to not interfere with normal activities and operations. In addition, shielding material must retain its effectiveness even after long periods in storage and exposure to light, heat, and humidity.

High performance computing simulations allow researchers to develop better ballistic shielding materials by examining the effects of ballistic impact frame-by-frame. Researchers can use simulations to test various armor components singly or in groups. Simulations may suggest effective material configurations that are not intuitively obvious from experimental data alone. After simulations narrow the field to the most promising armor configurations, they can be fabricated and tested under real-life conditions.

AHPCRC primary investigators Tarek Zohdi (associate professor, mechanical engineering, University of California, Berkeley) and Charbel Farhat (professor, aeronautics, astronautics, and mechanical engineering, Stanford University), research associate Philip Avery, and postdoc David Powell (both of Stanford) are bringing ballistic fabric modeling into the high performance computing arena by adapting existing codes for simulation and finite element analysis to run in parallel processing environments.

Time-lapse computer simulation of fabric deformation and rupture.



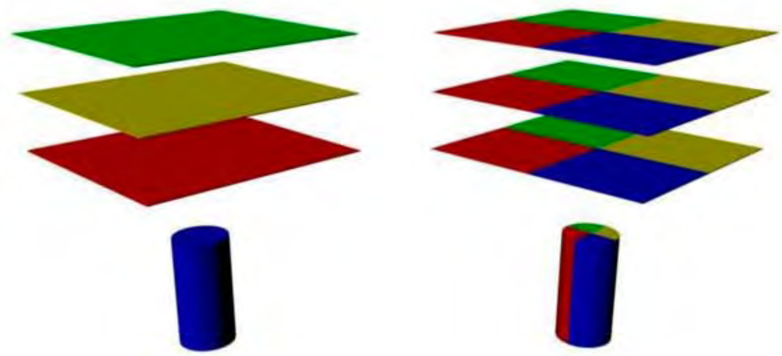
Zylon fabric test samples are ruptured using a cylindrical penetrator. (Photo and graphics courtesy David Powell, Stanford.)

Because there has not been an abundance of new materials to test, recent efforts have focused on optimizing the performance of existing materials. Fiber strength is important, but fabric geometry also matters, because projectiles can penetrate by pushing fibers aside, even if the fibers remain unbroken. Factors that affect performance of ballistic fabrics include the thickness and strength of the fibers, weaving patterns, and the method of attaching the fabrics to their substrates (pinned at the corners vs. fastened along the sides, for example). Customarily, the Army has evaluated ballistic fabrics by making and testing physical prototypes. Testing every combination of characteristics to find optimal combinations is time-consuming and expensive, however.

Ballistic impact produces multiple physical effects at high speeds—understanding these effects will assist in designing protective fabrics that can withstand impact by various types of projectiles. Using computer simulations to model the behavior of a fabric under impact from a high-speed bullet or shrapnel fragment requires the capability to model the nonlinear solid dynamics typical of materials undergoing rapid deformation caused by localized impact.

In addition to adapting existing software codes, Zohdi, Farhat, Avery, and Powell are building new capabilities into their modeling and simulation software to account for such rapid deformation effects. They are adding simulations for various projectile shapes, accounting for imperfections incorporated during the weaving of protective fabrics, examining the way the protective fabric is attached to the underlying struc-

ture, and simulating the propagation and growth of flaws in fabrics. They have begun preliminary work on modeling fiber-based composite materials in order to explore the properties of these complex systems.



Left: Conventional contact model performs calculations for each body using separate processors. Right: Areas in close physical contact are processed together, reducing data transfer between processors.

Putting the Model to the Test

The simulation method developed for this project represents ballistic fabrics from the fibril level up, so that the same method can be applied to many different materials, weaving types, and modes of attachment to a substrate. For both the simulation and the real-world fabrics, thin filaments called fibrils are twisted together into strands of yarn, which are then woven into fabric sheets. Fibril properties are relatively simple to model, they can be obtained readily from the manufacturer, and they are simple to test and verify.

The model addresses tensile strains only, as tension (rather than compression) is most important when assessing rupture properties due to ballistic impact. Because a fibril is very thin relative to its length, tensile deformation can be described as a one-dimensional response to an applied uniaxial stress. Axial strain for the fabric is assumed to lie in the region between 2% and 10% prior to rupturing. Zylon fabric, which was used in the experiments with which the simulations were compared, ruptures at 3% strain. Zylon yarn has 350 fibrils per strand, and the simulated yarn response is obtained by summing the responses for all the fibrils.

Misalignment, in which the directions of the fibril axes exhibit a statistical distribution, occurs during manufacturing (indeed, it is almost impossible to avoid). This misalignment is a beneficial property of the yarn. Individual fibrils fail at different times in response to stress, because of the variation in their orientation with respect to that stress. This causes a given yarn strand to fail gradually rather than catastrophically. Differences in yarn strands tend to be small, because the large number of fibrils in each strand average out statistically, but the misalignment effect is a necessary component of a good macroscale model.

The AHPCRC model treats a woven fabric as a network of nonlinear trusses (yarn) pinned together at nodes where two trusses meet. ("Nonlinear" refers to materials that do not experience strain in proportion to the amount of stress applied.) This model was constructed using FEM, a finite element modeling program used at Stanford. Sandia Laboratories' ACME contact library was added to FEM to supply appropriate algorithms to search for contact entities and to enforce contact constraints.

When simulations deal with parts of various bodies (e.g., a projectile or a sheet of fabric) that are in physical contact, such as during an impact event, significant amounts of information are passed back and forth between computer processors, which increases the time needed to complete the calculations. Optimizing the performance of the contact search proved to be dependent on the choice of subdomains, because separate processors perform calculations for each subdomain. Typically, subdomains group together elements that are in the same body. A more efficient method defines subdomains as those regions which are in close spatial proximity to each other, regardless of which body they are in (*see figure above*).

The problem of a small projectile striking a single fabric sheet presents an area of contact that involves only a few elements. This makes it difficult to divide the workload over more than about 10 processors. At the other extreme, when two sheets come together and the

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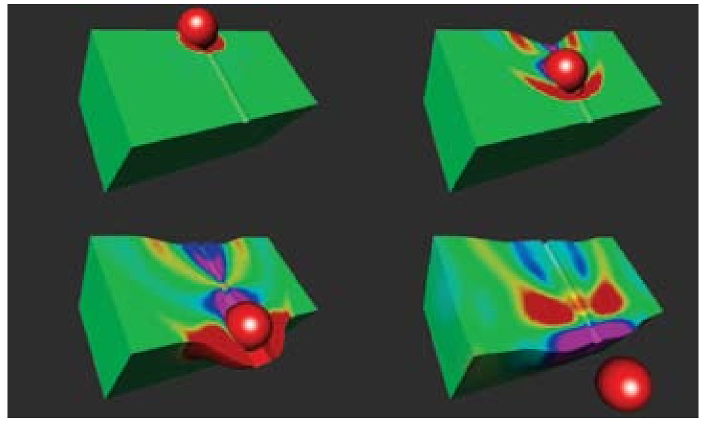
Simulating Fracture and Penetration

Understanding the effects of ballistic impact of ammunition or shrapnel on human soft tissues has the potential to aid medical professionals in treating battlefield injuries, planning reconstructive surgery, and understanding more about wound healing processes. In addition, this knowledge can be used to evaluate various materials and designs for ammunition and armor. Human testing of this type is of course impractical. Blocks of alternative tissue simulants, called ballistic gels, are used instead.

Constructing computer simulations of material behavior under shock or ballistic impact is especially difficult because complex changes occur rapidly. A soft material such as a polymer or ballistic gel absorbs and dissipates energy from the impact, deforms, and cracks, in less than a few milliseconds. Building a computer simulation that captures all of these changes requires repeatedly solving millions of equations to create a series of "snapshots" taken at the rate of millions of frames per second and extending over several milliseconds. Each change affects the changes after it, and physical effects interact to alter the course of events. In addition, each snapshot comprises millions of small sections (finite elements) of a structure, each interacting with and affecting the behavior of the adjacent sections. The number of computations required to construct a realistic simulation can tax the resources of even the best high performance computers. Thus, it is necessary to frame the problem and program the computational codes in a way that uses computing resources efficiently, without sacrificing accurate results.

AHPCRC researcher and assistant professor Adrian Lew and graduate students Raymond Ryckman and Ramsharan Rangarajan (mechanical engineering department, Stanford University), are working with AHPCRC staff scientist Mark Potts (High Performance Technologies, Inc.) to create and adapt methods for modeling the evolution of domains (regions with uniform properties) and crack paths so that they function in a parallel processing environment.



Simulation of a spherical projectile penetrating a ballistic gel. (Photo and graphics courtesy Adrian Lew, Stanford.)

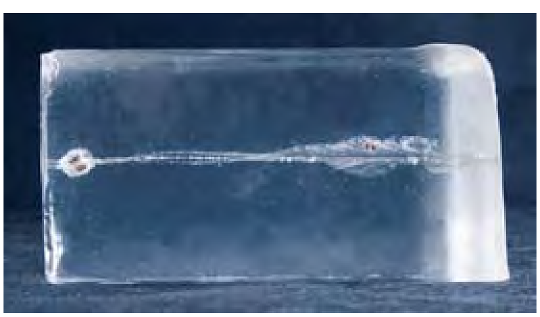
The group is devising methods to simulate soft materials undergoing fracture and penetration. When they began their work, there were no existing simulation methods that were sufficiently robust to carry out accurate calculations over the time scale of an actual impact event. Because of the computational resources needed for such an endeavor, any computer codes would have to be scalable; that is, the codes would need to run well on any number of available processors. The group needed to develop algorithms for complex motions and interactions between the projectile and the target that would work well in such an environment.

At present, a model is being constructed for the effects of a bullet hitting a ballistic gel. Ballistic gel simulations under development include shock, penetration, and contact effects, and the way the gel absorbs energy from an impact. Lew foresees future efforts that incorporate aspects of material modeling: how does impact with tissue or a polymer differ from impact with wood, metal, or concrete? What happens when friction-generated heat partially melts the polymer or gel? What are the effects of a projectile tumbling within a fissure? How does a network of cracks form and spread? The Stanford group is planning to compare their simulations with experimental studies conducted at the University of California at Berkeley at a later stage of the project.

Breaking the Lock-Step

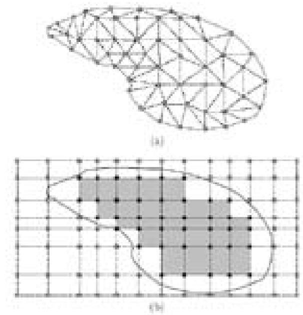
The AHPCRC group is currently working on a parallel code for nonlinear solid dynamics that incorporates an algorithm capable of asynchronously constructing the part of each snapshot corresponding to different spatial locations (parallel asynchronous time integration, or pAVI). This approach allows each section of a large problem to be computed at the speed and degree of detail that best suits the complexity of that section. This differs from conventional problem-solving approaches, in which differential equations for each of the millions of elements in a problem are integrated using the same time increments, using the same number of processors. Potts explains: “With the lock step approach, lots of computational time ends up getting devoted to solving nondescript sections of the problem using very small time steps where they otherwise could be solved using much larger time steps.”

For problems in which some sections are especially complex (e.g., complicated geometries, rapid shape changes), the time increments between individual calculations must be very small in order to capture the requisite degree of detail—in much the same way as high-speed video uses thousands of frames per second to capture the flight of a bullet or the impact of a falling drop of water. Dividing the complex parts of the problem among several processors allows for frequent updates without slowing down the overall process. Simpler or less important sections of the problem that do not require this degree of detail can proceed with fewer updates (larger time increments between calculations) and occupy fewer processors.



Photograph of a projectile path through a ballistic gel.

Thus, the pAVI approach reduces the need for trade-offs between accuracy and efficiency.



Top: A boundary-fitting mesh. Bottom: A mesh suitable for use with immersed boundary methods.

Redrawing the Boundaries

The mathematical approach taken by the AHPCRC group is based on numerical methods for solving partial differential equations, which track physical quantities that change continuously over time. A mathematical representation of a soft structure, such as a ballistic gel, is divided into many small elements, each of which changes shape in response to the simulated ballistic impact. As these elements stretch and bend away from their initial shape, the mathematics describing them becomes more complex. At some point, the calculations must pause, and a process known as “remeshing” draws new reference gridlines onto the deformed soft body, based on localized displacement and velocity fields. This procedure may need to be repeated many times during the course of a simulation, and it slows the calculation process considerably.

The Stanford group uses an adaptive remeshing algorithm based on an immersed boundary method (*see figure above*). This method, which is often used to simulate solid bodies moving through fluids (or gels, in this case), uses a mesh that encompasses the domain of the problem while only approximately following the boundaries between the soft body and the solid body passing through it. This makes generating the mesh much easier at the expense of complicating the imposition of boundary conditions. Implementing this concept for a three-dimensional problem is one of the major areas of research for this project, because of the ability of this method to overcome many of the difficulties associated with automatic mesh generation.

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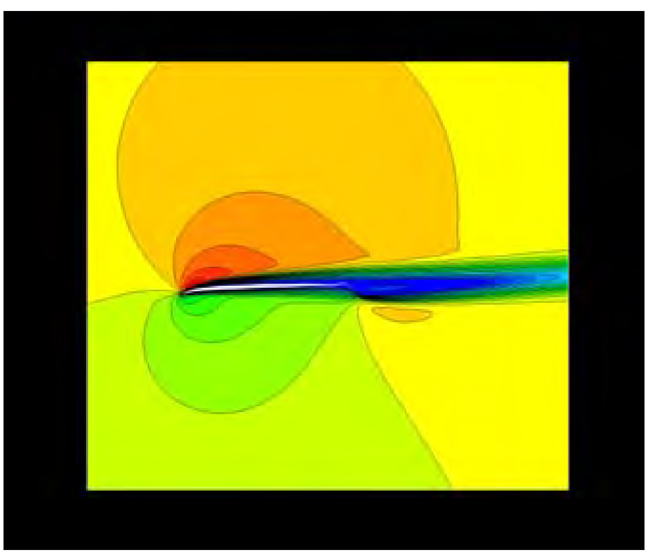
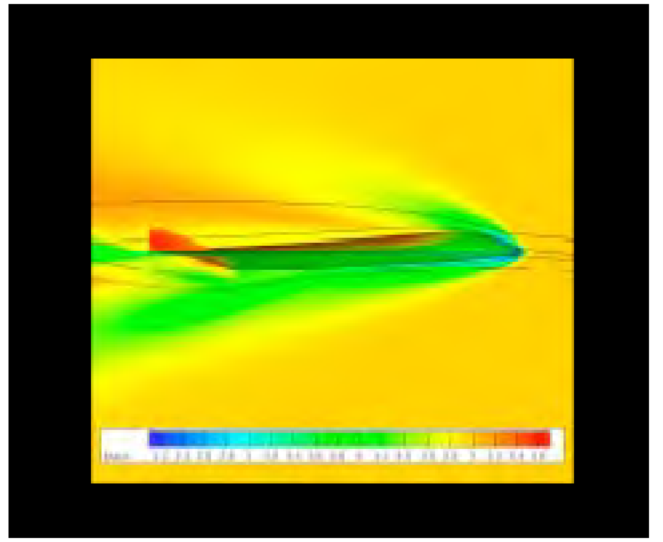
Optimizing Lift vs. Drag for Small Airfoils

Eagles soar, hummingbirds whir. How a bird flies depends largely on how big the bird is. Likewise, hummingbird-sized aerial surveillance and reconnaissance drones cannot depend on the same wing configurations and aerodynamics as their eagle-sized counterparts. As aerial vehicles become progressively smaller, the viscosity of the air takes on a greater importance (*see "All About Eddy," p. 7*). The ratio of the vehicle's inertial force (propelling it forward) to the viscous force of the air (holding it back) decreases. To keep a tiny vehicle airborne on just the amount of fuel that it can carry requires wings that can generate the most lift with the least drag.

AHPCRC researchers Professor Antony Jameson (Stanford University, Aeronautics and Astronautics) and his student Matt Culbreth are using massively parallel high performance computing simulations to optimize airfoil shapes and to identify the attainable performance limits for a given vehicle size and configuration. For a given amount of lift, the computations test various shapes to see which shapes produce the least amount of drag. By using computational models, the researchers can test a large number of vehicle designs much more rapidly than if they had to generate physical prototypes for each design.





This page: Two examples of airfoils generated by Jameson's group at Stanford. Colored areas represent pressure contours.

The Stanford researchers are performing their calculations using low values (1000 to 10,000) for the ratio of inertial to viscous forces, called the Reynolds number. Culbreth and Jameson have generated several airfoil configurations using a small number of geometry control points. Their work has produced airfoil geometries corresponding to a given pressure distribution, and they have successfully found the minimum amount of drag for a fixed lift coefficient.

The AERO-F simulation code that they use is massively parallel; that is, it runs on computer systems in which the work is distributed across many individual nodes. Each node consists of at least one processor, its own memory, and a link to the network that connects all the nodes together. The largest supercomputers have several hundreds of thousands of nodes in the same "box," but parallel systems can also consist of clusters of conventional computers linked in such a way that they pass information back and forth as seamlessly as a single supercomputer. AERO-F is also scalable, making it possible to run equally well on systems of various sizes.

Computer simulations have already identified promising airfoil shapes that run counter to an engineer's normal intuition—and that Nature never thought of. Camber (the difference in curvature between the top

and bottom surfaces of an airfoil) can be optimized to reduce drag or to increase the angle at which the aircraft begins to stall. If the curvature is greater on the top surface, the camber is positive, while a greater curvature on the bottom surface produces negative camber—a configuration known as a supercritical airfoil shape, which has been used to improve the lift-to-drag ratio for high-speed aircraft.

Micro aerial vehicles are typically built for miniaturization rather than speed, and flapping wings are a necessity to generate enough lift to remain aloft. Simulations have identified combinations of flapping frequency and amplitude that do—and don't—generate sufficient lift. The simulations show a trail of vortices behind the flapping wing, which can either help the vehicle (or bird) stay aloft or hinder it. (*See next article for more about this work.*)

Recent work is moving toward a 3D unsteady optimization of flapping motions for hovering and forward flight. The goal is to couple an advanced computational fluid dynamics code such as AERO-F with the optimization libraries developed elsewhere in AHPCRC in order to synthesize wing motions and deformations that optimize a specific performance metric.

Several iterations of a base mesh have been generated for the initial optimizations, incorporating refinements to improve accuracy, convergence, and resolution of flow features, while attempting to minimize the computational cost as much as possible. (*See previous article for more about meshing schemes.*)

The appropriate solver parameters are being determined for the AERO-F code running unsteady simulations at Reynolds numbers between 1,000 and 10,000. This process involves determining how to automate flow solutions and the post-processing of results so that they can be integrated with the optimization codes. At present, simulations involving wing pitching and plunging are being prepared to assess the trade-offs between mesh density and the ability to capture vorticity. ✮

All about Eddy

Airfoil modeling is not a new science, although steady advancements in computing power enable the creation of simulations with an unprecedented degree of complexity. Several methods exist for expressing fluid flow in mathematical terms.

Large eddy simulation (LES) is a technique for solving the differential equations associated with turbulent flow. The system of airfoil and flowing fluid is represented by points on a grid, and calculations are carried out at these points. A finer-meshed grid produces a greater accuracy, but is more expensive in terms of computer resources and time requirements. In the LES method, simulations are generated for only the larger eddies, and the smaller eddies are handled using a sub-grid scale model. LES represents an intermediate level between direct numerical simulation (DNS), which models turbulent motion at all relevant scales, and the more approximate Reynolds-averaged Navier–Stokes (RANS) model.

In variational multiscale LES, calculations are separated into two or more groups that address different size scales. The filters used in the LES method are replaced by variational projections, an approach that produces greater efficiency and accuracy than the conventional LES method.

Detached eddy simulations (DES) uses a RANS method to solve regions that have less than a specified turbulent length scale and that are near solid boundaries. If the turbulent length scale exceeds the grid dimension, the regions are solved using LES. The DES method requires less grid resolution than the LES method, which reduces the cost of the computation.

Source: Adapted from Wikipedia.

Flapping and Twisting Wings

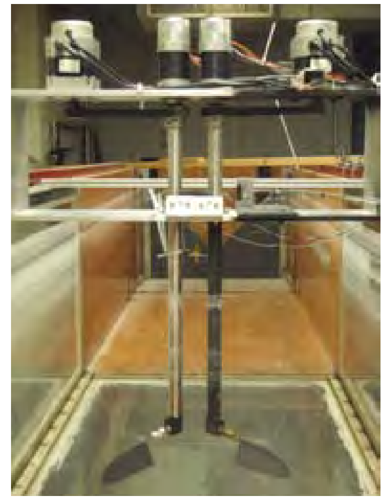
Building a robotic hummingbird is probably not the first thing one associates with Army research, but bird-sized robotic aerial vehicles are much in demand. Micro aerial vehicles, or MAVs, could perform surveillance, hazardous materials detection, terrain mapping, or data relay functions in situations where it would be hazardous or impractical to send humans. MAVs don't need sleep, and they don't get bored by looking at the same terrain for hours at a stretch. Unmanned aerial vehicles (UAVs), larger counterparts to the MAVs, have proven useful for military operations in Afghanistan, but the current generation of vehicles requires a runway for takeoff, and they are unable to hover.

AHPCRC researchers from New Mexico State University are working on a robotic hummingbird wing to gain insight into how to mimic a hummingbird's maneuverability. They have incorporated information from videos, provided by Bret Tobalske (then at the University of Portland, now at the University of Montana), of the vortices that live hummingbirds make as they fly. Hummingbird wings flap and twist, creating eddy currents that give the bird lift and momentum.

Mingjun Wei and Banavara Shashikanth, NMSU assistant professors of mechanical and aerospace engineering, head up the project. The late James Allen, NMSU assistant professor of mechanical engineering, oversaw the project in its early stages. Prof. Tom Burton, department head, was instrumental in bringing the NMSU group into the AHPCRC program, and he participates in the research group meetings. Prof. Charbel Farhat of Stanford University is providing additional computer simulation work on lift and drag. NMSU graduate students Tao Yang, Humberto Bocanegra Evans, Mohammad Mazharul Islam, and Ramiro Chavez receive AHPCRC support.

3:1 scale model of a hummingbird wing.

The research team is building computer simulations that will help them understand and imitate the complex wing motions that come naturally for small birds and insects. At the scale of a small bird, you have to deal with factors that don't even register for large aircraft (or even large birds)—a gust of air from a building's exhaust vent, or drag generated by the viscosity of the air, for example. Birds and insects have been dealing with wind gusts, fuel intake and consumption, lift and drag, and obstacle avoidance issues for millennia. They fly under all sorts of weather conditions, alone or in flocks or swarms. (*See previous article for more on small bird flight.*)



Mechanical wing testing in a low-turbulence flow tank at NMSU. (Photos and graphics courtesy Mingjun Wei, Banavara Shashikanth, NMSU.)

How does a bird do it?

Among the problems an MAV designer has to face is how to gather and store enough energy to sustain flight without making the vehicle too heavy to fly. The hummingbird does this by feeding every 10–15 minutes during its waking hours and slipping into a deep sleep state at night. It would be impractical to operate an MAV on this schedule, so efficient energy usage is key to the success of these vehicles.

Birds and insects make very little noise as they fly, and they recover quickly if they graze a tree branch or other obstacle. These will be important features in designing MAVs, along with agility and maneuverability. Hummingbirds are especially agile—they can take off from a stationary position, hover, and change directions in midair. During flight, they sweep their wings forwards and backwards while plunging (oscillating) and pitching (rotating) their wings, tracing figure-eight paths with their wing tips.

Building a better bird

The earthbound engineers at NMSU are using high-performance computer (HPC) simulations to explore the best combinations of plunging, pitching, and twisting motions for producing thrust. They are testing various frequencies and amplitudes of the flapping and twisting motions to determine what works best. They are developing a three-dimensional HPC version of a code based on a modified immersed boundary method (*see page 5*), which models a flowing fluid interacting with a flexible, elastic structure (such as a wing) by computing the flow and the structure simultaneously on the same mesh grid in a fully-coupled fashion. Dynamical models for flow–structure interactions are being developed for some simple configurations. Wei and Yang are doing numerical simulations, and Shashikanth and Islam are developing theoretical models.

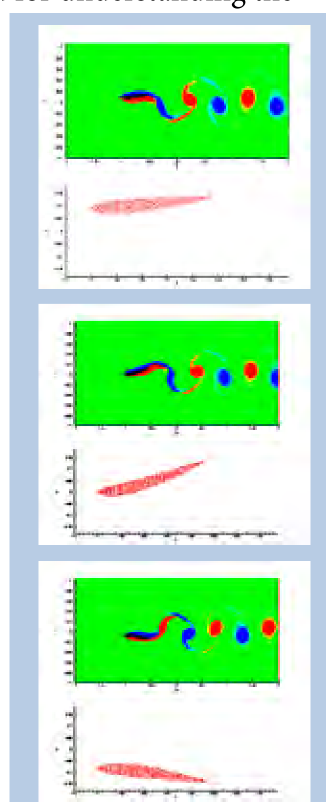
Evans, Chavez, and their co-workers have built a model wing that they are testing in a low-turbulence water channel, and they will use their findings to validate and improve their computer models. This will enable them to find useful configurations, maybe even ones that Nature hasn't thought of yet, and save their mechanical model-building resources for the best candidates. Preliminary runs have been conducted on a mechanical model wing with two degrees of freedom of motion, and the concept design has been completed for a wing with three degrees of freedom.

Farhat's group at Stanford is pursuing an alternative simulation approach based on a combination of higher-order ALE (Arbitrary Lagrangian Eulerian) and embedded methods. This approach is especially useful for modeling the interactions of moving flexible wings with air streams, because it enables calculations based on the interaction of both solid and fluid reference frames.

To this effect, they have developed an upgraded version of the massively parallel AERO-F computer code that features a number of explicit and implicit schemes that satisfy their discrete geometric conservation laws (DGCLs)—a set of conditions imposed on a moving computational grid in order to preserve the accuracy and stability of the calculations when integrated over a period of time. The formal accuracy of these schemes was proven to be identical to their counterparts on fixed grids. The team has analyzed the amount of thrust generated by high-frequency plunging motions using AERO-F 's large eddy simulation (LES) capabilities. More recently, they simulated flapping motions (active plunging coupled with passive pitching) for various frequencies.

In particular, LES runs were performed at Stanford on massively parallel processors to investigate numerically the existence of a critical frequency, below which drag is generated and above which thrust is produced. The simulations clearly demonstrated the existence of such a critical frequency. Previous experimental studies had shown a surprising onset of nonsymmetric wake patterns at higher frequencies. The Stanford simulations also predicted these patterns, which produce both lift and thrust.

Insights gained through computational modeling and simulation provide valuable guidance in choosing configurations and operational parameters for real-world mechanical wings, and for understanding the factors that go into making a wing that works. Back at NMSU, work continues on improving the physical wing models for testing in the water channel. The research group also plans to build a computational model of a micro aerial vehicle with flapping wings. They will test their models using plunging, pitching, and twisting motions alone and in combination to determine which motions produce the most thrust. ✯



Vortices created by a flapping flexible airfoil in an incoming flow, modeled over a period of 0.5 second.

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Dick Pritchard, AHPCRC Program Manager

Since 2008, Dr. Richard (Dick) Pritchard has been Program Manager for AHPCRC. He is responsible for the infrastructure and administration elements of the program and for managing the relationships with the Consortium's members. He manages the AHPCRC staff scientists and supports collaboration activities across the research technical areas, and industry/ HPC vendor partners.

Pritchard, who is based in Dayton, Ohio, works for High Performance Technologies, Inc. (HPTi), the administration and user services member of the AHPCRC consortium. Prior to coming to HPTi, he was the Director of Federal Programs at the Ohio Supercomputer Center. He was previously employed by Nichols Research Corporation and BDM International.

Pritchard is a retired U.S. Air Force Colonel with 12 years of active duty service and 18 years as a reservist. His technical background is in computational chemistry and materials. He received his B.S. degree in chemistry from Duke University and his M.S. and Ph.D. degrees in chemistry from the Ohio State University. He has 40 years of experience as a researcher, military officer, and technical/program manager in defense research and development. ✯

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Barbara Bryan, AHPCRC Research and Outreach Manager

Barbara Bryan, who has managed AHPCRC user services at the NASA Ames facility since it opened in 2007, was promoted to Research and Outreach Manager in 2008. Ms. Bryan replaces Charles Peavey, who has assumed other duties at High Performance Technologies, Inc. (HPTi). Ms. Bryan was a staff member with the first AHPCRC Consortium at the University of Minnesota before coming to HPTi.

Bryan works with Dr. Charbel Farhat, the Center Director, and her office is at Stanford University. She works with the Cooperative Agreement Manager and Center Director to communicate research objectives and report on accomplishments, and align and identify potential HPC resources on at-institution or DoD platforms. She also works with each university's outreach manager and Consortium representative to establish an integrated outreach program emphasizing the Army research and HPC/computational science objectives.

Ms. Bryan has extensive experience in high performance computing operations and support, parallel programming, scientific applications, computer security, and scientific visualization. She has managed R&D projects, outreach programs and IT infrastructure at AHPCRC for 10 years. ✯

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Cook Receives Presidential Early Career Award for Scientists and Engineers

Jeanine Cook, a principal investigator for the Army High Performance Computing Research Center (AHPCRC), has received the prestigious Presidential Early Career Award for Scientists and Engineers (PECASE). President George W. Bush presented the award to Cook on December 19, 2008, at the White House.

Cook, an associate professor at New Mexico State University's Klipsch School of Electrical and Computer Engineering, specializes in micro-architecture simulation techniques, performance modeling and analysis, workload characterization, and micro-architectural power optimizations for high performance computing systems. She directs the Advanced Computer Architecture Performance and Simulation Laboratory at NMSU.

The PECASE award is one of the highest honors that the United States government bestows on outstanding scientists and engineers beginning their independent careers. About 50 U.S. researchers receive PECASE awards each year, and an individual can receive only one such award during his or her career.

Cook's work with the AHPCRC consortium focuses on time-efficient performance modeling and analysis of Army HPC applications, with the intention of reducing the amount of time and money necessary to configure computer systems and make procurement decisions. Such modeling and analysis can also assist in identifying optimal application-to-architecture mappings and optimizing code performance, operating system services, and hardware design. She has worked with researchers at the University of Texas, El Paso, to design and implement Chimera, an AHPCRC-sponsored heterogeneous computing cluster that links commercial multicore processors, GPUs, FPGAs, and accelerators. Chimera is used to test applications for their ability to perform well on a variety of processors, and to identify ways of reducing execution time using specialized resources.

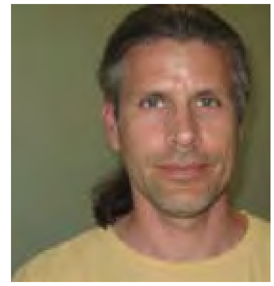
Jeanine Cook
Photo courtesy of New Mexico State University

Cook was nominated for the PECASE award by her colleagues at Sandia National Laboratories for her work in performance analysis. Cook built a simulator to pinpoint the sources of Sandia application performance problems.

In an NMSU press release, Cook, who was paralyzed from the waist down after a 1982 automobile accident, stated, "I want [the award] to heighten attention for people with disabilities and secondly, I want it to heighten attention for young women. I want young women to have role models to say, 'If she did that, I can do that too.' I really want the world to see that people with disabilities are people—we are people—we're not to be afraid of. We can be treated just like anybody else. We're not stupid, we're not helpless, we're just people."

In the press release, NMSU interim president Waded Cruzado praised Cook, the daughter of an Italian father and a Hispanic mother: "Jeanine is a prime example of the outstanding faculty talent New Mexico State University strives to recruit and retain to help this land-grant university's mission and commitment to providing the highest quality of education for its students. The NMSU family is very proud of Jeanine's accomplishments and the honor and recognition that she has brought to herself and this university. The distinction of receiving the PECASE award demonstrates how women, minorities and persons with physical challenges can overcome the many obstacles placed before them to succeed and exceed in their careers." ✯

Scalable Networks Technologies Receives Army Modeling and Simulation Award



Rajive Bagrodia (left), Richard Meyer (right), Scalable Networks Technologies

Rajive Bagrodia, president of Scalable Networks Technologies, was one member of the Army's Future Combat Systems (Brigade Combat Team) Communications Effects Server Modeling and Simulation Team, which was presented with an Army Modeling and Simulation Award at the 2008 Interservice/Industry Training, Simulation and Education Conference (ITSEC) in Orlando last December.

The award recognizes the Communications Effects Server (CES), an extension of Scalable Networks Technologies' QualNet software. (AHPCRC is supporting the deployment of QualNet at ARL's Mobile Networks Modeling Institute.) QualNet and CES are HPC compatible, which was one reason that this team won the award, according to Richard Meyer, the company's Director of Engineering

The CES is a simulation of the Future Combat System network transport layer that represents radios, ground and airborne relays, and the Warfighter Information Network-Tactical gateways to satellite systems connecting the FCS network. The CES can currently simulate message delivery among at least 5000 nodes running in a near real-time environment, according to the award nomination.

The nomination states that this model runs in a multiprocessor environment, and is "one of the largest mobile ad hoc network models to run in real time, thus providing the Army with a simulation/stimulation M&S capability unequaled throughout the Department of Defense or the commercial communications industry." ✭

Multiscale Ballistic Fabric Nets

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contact is distributed evenly across the entire problem (approximately one million degrees of freedom), the algorithm scales well up to about 200 processors. Optimum scalability requires at least 50,000 degrees of freedom per processor. The majority of problems expected to be of interest to producers and users of ballistic fabrics will involve a combination of localized and distributed contacts, so the scalability of the algorithm should fall somewhere between these two extremes.

Ballistic impact has been simulated for a 50-caliber (0.5-inch) cylindrical projectile and a Zylon square 10 inches on a side, fastened at the corners to a substrate, for comparison with experimental studies done at Berkeley. In both the experiments and the simulation, fabric failure occurred at the corners as a result of impact.

In the region of the ballistic limit (the impact velocity below which penetration does not occur), the simulation agreed closely with the experimental results. The simulation predicted a ballistic limit of 39.6 m/sec, which compares well with the experimentally observed ballistic limit of 39.3 m/sec. ✭

Simulation of Fracture and Penetration
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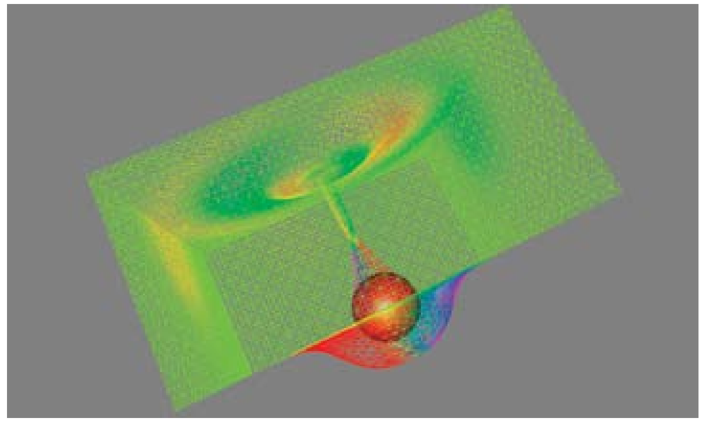

Mesh structure for projectile impact simulation.

Ongoing Work

When many calculations are going on all at once, it is necessary to build elements into the computer code that keep the calculations on track and to weed out solutions that are mathematically correct, but physically meaningless. Toward this end, the group is investigating a new approach to control the high-frequency velocity oscillations that appear with the adoption of explicit time discretizations such as AVI. These oscillations are enhanced in the presence of shocks, typical of penetration problems or contact problems. This is critically important for modeling the amount and spatial distribution of energy absorbed by a ballistic gel when a bullet penetrates it.

Raymond Rickman is working on a rigid bodies algorithm that will model the contact between a bullet and a ballistic gel. He has begun parallel runs with the algorithm using Army computing clusters, and has shown that the problem is scalable. Ramsharan Rangarajan has demonstrated that a new immersed boundary method for solid mechanics with nonhomogeneous boundary conditions converges quadratically (a measure of how fast a calculation reaches a solution), as required by many solid mechanics problems. This algorithm is intended to be part of the automatic remeshing capability for the penetrating bullet problem.

Simulations for rigid body impact on elastic bodies have been performed using as many as 128 processors and 3 million degrees of freedom. Simulations for penetration have been started, using a model that incorporates a small pre-existing hole in the elastic medium. As the work progresses further, a penetration algorithm will be added so that the pre-opened hole will not be necessary. A self-contact algorithm is also in the works, which will enable the simulation of the cavity collapsing after the bullet passes through.

The AHPCRC group plans to adapt their method to model the rupture of the material by the projectile. They will also develop the first parallel version of the penetration problem in gelatin that will run scalably on HPC platforms. This year, they will perform the first parallel-explicit contact runs for the bullet. ✮

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AHPCRC Publications and Presentations April 2008–April 2009

Project 1–1: Multiscale Ballistic Fabric Nets

Multi-scale Modeling and Large-scale Transient Simulation of Ballistic Fabric. D. Powell, C. Farhat, , T. I. Zohdi. Oral presentation CO-03, Proceedings of the 26th Army Science Conference, Orlando, FL, December 2008.

Project 1–2: Simulation of Fracture and Penetration

• A discontinuous-Galerkin-based immersed boundary method. Adrian Lew and Gustavo Buscaglia. *International Journal for Numerical Methods in Engineering, 76 (4),* 427–454, 2008. DOI: 10.1002/nme.2312.
• Towards Long-time Simulation of Soft Tissue Simulant Penetration. Ramsharan Rangarajan, Raymond Ryckman, Adrian Lew. Poster PP-04, Proceedings of the 26th Army Science Conference, Orlando, FL, December 2008.

Project 1–4: Flapping and Twisting Aeroelastic Wings for Propulsion

• Galerkin Reduced Order Models for Compressible Flow with Structural Interaction. Matthew F. Barone, Daniel J. Segalman, Heidi Thornquist, Irina Kalashnikova. *American Institute of Aeronautics and Astronautics (AIAA) Paper No. 2008−0612*, 46th AIAA Aerospace Science Meeting and Exhibit, Reno, NV, January 2008). (Available at www.stanford.edu/~irinak/reno08.pdf)
• Flapping and Twisting Aeroelastic Wings for Propulsion. Humberto Evans (presenter), Mingjun Wei, Poster presentation, AHPCRC exhibit, Supercomputing 2008, Austin, TX.
• Flight of a Rufous Hummingbird Robotic Model-PIV Measurements. H. Bocanegra Evans, R. Chavez Alarcón, P. Ferreira de Sousa, B. Tobalske, J. J. Allen. 61st Meeting of the APS Division of Fluid Dynamics, San Antonio, TX, Nov. 23–25, 2008.
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Project 2–3: Protein Structure Prediction for Virus Particles

• Comparison of two approaches in the parallel computation of secondary structure topology determination. Saeed Al Haj, Jing He. Poster, IEEE Bioinformatics and Biomedicine Conference, Nov 3–5, Philadelphia.

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Project 4–3: Simulation & Modeling to Enhance the Performance of Systems of Multicore Processors

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Project 4–6: Hybrid Optimization Schemes for Parameter Estimation Problems

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